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Maritimes Region | **Région des Maritimes**

Limit Reference Point for Southwest Nova Scotia / Bay of Fundy Spawning Component of Atlantic Herring, (*Clupea harengus*) (German Bank and Scots Bay)

Point de référence limite pour la composante de reproducteurs du hareng de l'Atlantique, (*Clupea harengus*), dans le sud-ouest de la Nouvelle-Écosse et dans la baie de Fundy (banc German et baie Scots)

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ABSTRACT

In accordance with the Terms of Reference for the meeting, the available data were examined in order to determine candidates for a limit reference point for the Southwest Nova Scotia / Bay of Fundy Spawning Component of Atlantic Herring, *Clupea harengus*, and a rationale is provided for the recommended values. Five sources of information are discussed in this research document: historical stock status advice; the presence or absence of spawning components; the fate of individual year classes (cohorts) over time (mortality rate trends and proportion of juvenile fish); historical landings; and acoustic survey relative index.

With the evidence of the decline in spawning grounds, targeting of juveniles in the fishery, declines in catches, as well as the science advice indicating the need for rebuilding, it is proposed that the 2005 to 2010 average acoustic survey value be identified as the conservation limit reference point for Southwest Nova Scotia / Bay of Fundy herring (German Bank and Scots Bay). The stability at the 2005-2010 level is support for this as the limit reference point and provides data from which to select a point, below which, the risk of serious harm is unacceptable. Other considerations that lead to the selection of this point relate to the objective of avoiding negative impacts to the ecosystem and long-term loss of fishing opportunities. Ecosystem considerations include herring's role as a forage fish, and long-term loss of fishing opportunities in the case of stock collapse and possible decades required for recovery to occur.

RÉSUMÉ

Conformément au cadre de référence de la réunion, les données disponibles ont été examinées afin de définir les candidats au point de référence limite pour la composante de reproducteurs du hareng de l'Atlantique, *Clupea harengus*, dans le sud-ouest de la Nouvelle-Écosse et dans la baie de Fundy et une justification est fournie pour les valeurs recommandées. Cinq sources d'information sont abordées dans le présent document de recherche : les avis historiques concernant l'état du stock; la présence ou l'absence de composantes de reproducteurs; le sort des classes d'âge individuelles (cohortes) au fil du temps (tendances des taux de mortalité et proportion de poissons juvéniles); les débarquements historiques et l'indice relatif du relevé acoustique.

Au vu de la preuve du déclin des frayères, du ciblage des juvéniles dans la cadre de la pêche, de la baisse des prises, ainsi que des avis scientifiques faisant valoir la nécessité d'un rétablissement, il est suggéré d'utiliser la valeur moyenne du relevé acoustique de 2005 à 2010 comme point de référence limite de conservation pour le hareng du sud-ouest de la Nouvelle-Écosse et de la baie de Fundy (banc German et baie Scots). La stabilité de 2005 à 2010 appuie ce choix de point de référence limite et offre des données permettant de choisir un point en dessous duquel le risque de nuire au stock est inacceptable. D'autres facteurs aboutissant au choix de ce point sont liés à l'objectif visant à éviter les répercussions négatives sur l'écosystème ainsi que la perte des possibilités de pêche à long terme. Les facteurs liés à l'écosystème incluent le rôle du hareng en tant que poisson-fourrage et la perte des possibilités de pêche à long terme dans le cas de l'épuisement du stock et du rétablissement qui prendrait probablement des décennies.

BACKGROUND

The Precautionary Approach (PA) provides guidance to industry and government fisheries managers on how to manage fisheries. In resource management, the PA in general is about being cautious when scientific information is uncertain, and not using the absence of adequate scientific information as a reason to postpone or fail to take action to avoid serious harm to the resource (DFO 2009a). The Privy Council Office Guidance (2003) on implementing the PA instructs that "precautionary measures should generally be implemented on a provisional basis; that is, they should be subject to review in light of new scientific information or other relevant considerations, such as society's level of protection against risk". Accordingly, the data that are currently available will be used for calculating reference points and future updates are possible when appropriate.

The limit reference point (LRP) represents the stock status below which serious harm is occurring to the stock. At this stock status level, there may also be resultant impacts to the ecosystem, associated species and a long-term loss of fishing opportunities (DFO 2009a). For many stocks, setting the LRP in biomass terms is suitable, but other units may be used to indicate stock status where appropriate. Reference points will usually be determined using standard biomass and harvest metrics; however, for a number of stocks, such measurements are not available. In these cases, precautionary management actions should be based on the estimates of productive potential and harvest that are the most appropriate for the stock of concern and data available, with the objective of avoiding serious harm to reproductive capacity of the stock.

In general, as long a time series as possible should be used in establishing reference points for a stock. Many stocks will show substantial variation in productivity over a long time series, and this variation should be taken into account when setting the reference points. As a general rule the only circumstances when reference points should be estimated using only information from a period of low productivity is when there is no expectation that the conditions consistent with higher productivity will ever recur naturally or be achievable through management (DFO 2009a). For example, in a case where the LRP cannot be derived from the history of the status of a stock, the state from which a secure recovery has been demonstrated under similar conditions might be the best scientific basis for estimating a LRP (DFO 2009a).

Rebuilding can be challenging for stocks with very low abundance since these stocks generally have poor productivity. In these circumstances, concerted action is required to ensure stock recovery occurs (DFO 2009a). It is essential that rebuilding strategies and objectives that are consistent with the PA are identified although there may be some flexibility in the time frame required for achieving these objectives (DFO 2009a). In many cases, rebuilding of a stock to more sustainable levels has to be seen in terms of a long time horizon.

A regional peer review meeting was held at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia, during February 6 to 9, 2012, to review PA references for a variety of fisheries resources in the Maritimes Region. The purpose of the meeting was to peer review the science input that will form the basis for fishery-specific reference points. Recommendations from this meeting will then be used to provide science input to Fisheries Advisory Committees where Fisheries Management and the fishing industry will discuss and refine reference points prior to their implementation (DFO 2012).

Herring, *Clupea harengus*, stocks in the Southwest Nova Scotia / Bay of Fundy (SWNS/BoF) herring spawning component have been of concern for a decade or more, and stock status reports have indicated the need for rebuilding at least since 2001 (DFO 2001, 2002, 2003a,

2004, 2005, 2006, 2007, 2008, 2009b, 2010, 2011a). An analytical model is not used for the SWNS/BoF herring spawning component, but the 2011 Framework review recommended the following indicators for signs of change (DFO 2011b):

- Acoustic survey biomass trends,
- Fishermen input,
- Numbers or proportion at age in catch,
- Trends in exploitation rates from survey, and
- Mortality rate trends based on age composition, F=Z-M.

These were the indicators that were considered in the most recent assessment (DFO 2011a) for providing management advice.

The available data were examined in order to determine candidates for a LRP and a rationale was provided for the recommended values. Five sources of information are discussed in this research document:

1. Historical stock status advice,
2. The presence or absence of spawning components,
3. The fate of individual year classes (cohorts) over time (mortality rate trends and proportion of juvenile fish),
4. Historical landings, and
5. Acoustic survey relative index.

ANALYSES

HISTORICAL STOCK STATUS ADVICE

Herring stocks in for the Southwest Nova Scotia / Bay of Fundy herring spawning component have been of concern for a decade or more and stock status reports have indicated the need for rebuilding at least since 2001 (Table 1).

SPAWNING COMPONENTS

According to Petitgas *et al.* (2010) a stock is depleted when biomass is severely reduced while its stock structure and habitat use patterns remain intact. A stock is collapsed when both have occurred. When population structure remained largely intact, rebuilding could be achieved within a relatively short time. In contrast, when age and contingent structure were damaged substantially, recovery time exceeded a decade or more (Petitgas *et al.* 2010). Analyses of North Sea Herring indicate that the collapse occurred in a progressive way through different sub-units (Stephenson 1997) and that, therefore, from a precautionary point of view, there is a need to ensure spatial diversity of spawning components (Dickey-Collas *et al.* 2010).

The importance of the persistence of all spawning components was recognized with the development of a Spawning Stock Technical Working Group in 1995. This working group, which was composed of industry and DFO members, was formed at industry's request to address concerns about the health of the fishery given the 1994/95 fish distribution, low fat content, and larval observations. They identified the spawning groups that were relevant in recent years and provided suggestions for the management of these grounds (DFO, internal communication). They ranked spawning grounds by relative importance as:

1. German Bank,
2. Scots Bay,
3. Seal Island, and
4. Little Hope.

Trinity Ledge was not included as it had already been severely reduced. Little Hope is now managed as part of the Coastal Unit and is not considered part of the SWNS/BoF spawning component.

The 2003-2010 Scotia-Fundy Herring Integrated Fisheries Management Plan also recognized the importance of spawning ground protection and specifically identified it as an element of the conservation objective of maintaining the reproductive capacity of herring in each management unit (DFO 2003b). Four main spawning grounds have been documented for the SWNS/BoF spawning component: German Bank, Scots Bay, Seal Island, and Trinity Ledge. Spawning ground area catches as a proportion of the overall catch are shown in Figure 1, which demonstrates the substantial decrease in the contribution of Seal Island and Trinity Ledge to the catch. Similarly, Figure 2 shows that Trinity Ledge makes up a very small proportion of the total acoustic estimates. Between 2001 and 2010, annual acoustic surveys on Trinity Ledge and occasional acoustic surveys in the Seal Island area document spawning aggregations, which are on average 2% and <0.3% of the average spawning aggregations on German Bank in the same time period (data from Table 2, DFO 2011a). Figure 2 also shows the reliance on German Bank.

Summary of Spawning Components Information

The reduction in the amount of fish on the Trinity Ledge and Seal Island spawning grounds of the SWNS/BoF spawning component is an indication of the declining health of the stock. It is difficult to quantify at what point a spawning ground is considered to be at a critical level since some spawning fish may still be present even at very low biomass levels, but the decrease in the contribution of Trinity Ledge and Seal Island to the catch is a reason for concern. A further concern is the high and increased reliance on German Bank.

THE FATE OF INDIVIDUAL YEAR CLASSES (COHORTS) OVER TIME

Total mortality (Z) was calculated by comparing catches of individual cohorts in successive years. Z_{adult} calculates a Z from the catch of ages 4 to 7 in year y and the catch of ages 5 to 8 in year y+1 in the following manner:

$$Z_{adult} = \ln\left(\frac{Catch\,Age\,4-7_{year\,y}}{Catch\,Age\,5-8_{year\,y+1}}\right)$$

Z_{juv} was calculated using the catch of ages 2 and 3 in year y and the catch of ages 4 and 5 in year y+2. The lag of two years was used in the calculation of Z_{juv} to ensure that both cohorts were fully recruited to the fishery.

$$Z_{juv} = \ln\left(\frac{Catch\,Age\,2-3_{year\,y}}{Catch\,Age\,4-5_{year\,y+2}}\right)$$

To reduce the amount of inter-annual variability, The Z values in Figure 3 are weighted averages of Z from three successive years.

There is evidence from past analyses and landings data that the herring population declined in the mid 1970s, following years of high total mortality on both juveniles and adults. In the period between the late 1970s and mid 1990s, total mortality was low on juveniles and high on adults. However, in the late 1990s, when concern was expressed about the herring population and catches declined, the calculated values for Z were high on both juveniles and adults, which is likely more pressure than the population can sustain.

The catch of each cohort was summed and the proportion of the total catch of each cohort that was taken at ages 1 to 3 was calculated (Figure 4). This mirrors the information presented in Figure 3. A high proportion of cohorts were taken at ages 1 to 3 in the 1960s and early 1970s, but then there was a decrease in targeting of juveniles between late 1970s and late 1990s. In the late 1990s cohorts are once again caught in a high proportion at younger ages.

Summary of the Fate of Individual Year Classes over Time

The information presented in Figures 3 and 4 demonstrates that in recent years, there has been increased fishing pressure on juveniles at a time when there is concern about stock status, but it would be difficult to define a reference point based on these data. Recognizing this issue, the herring fishing industry has put rules in place to decrease the targeting of juveniles, as of the 2011 fishing season.

HISTORICAL CATCH

Historical reported landings and annual quota are presented in Figure 5. Reported landings were adjusted in the 1980s and 1990s to account for short-falls in the official statistics (Stephenson 1993). Purse seining began in the early 1960s, and catches dramatically increased. The figure clearly illustrates that even after the quota was introduced in 1977, it was not prohibitive to landings up to about 1992. Between 1977 and 1992 the quota was exceeded in 13 of the 16 years. Beyond 1992 the introduction of dockside monitoring greatly increased the reliability of reported landings. From 2002 to the present, landings generally track the quota, except for 2010 when an industry decision to limit the amount of small fish left about 10,000 t in the water.

Landings have varied as much as 70,000 to 100,000t from one year to the next even without a quota. A 5-year moving average beginning in 1963 was used to smooth the annual variability of the landings (Figure 6). The figure shows that the fishery peaked in the early 1970s, declined in the early 1980s, then increased again in the late 1980s to early 1990s, when it declined dramatically. Landings increased slightly into the early 2000s, but have been declining since about 2003 to a low level. Despite the greatly reduced landings since 1993 and the assumed decrease in fishing mortality rate, total mortality (Z) has remained high on adults and has increased to a high level on juveniles (Figure 3), indicating that the proportional decrease in population biomass is likely at least as great as the decrease in landings. If the decline in landings was entirely driven by the decrease in total allowable catch (TAC), then with the drop in F there should be a corresponding decline in Z, but this was not the case (Figure 3), such that decline in catch is reflecting a decrease in the population. Thus, the landings data track the perception of stock status over the time series even with all the outside influences of market and availability.

If the landings are proportional to the population biomass and therefore reflective of the stock's size, then the historical data may provide an indication of where the stock is relative to the past. While the pattern in Z for adults suggests some consistency in fishing mortality over time (Figure 3), there is high inter annual variability which would make it difficult to define an LRP based on these data.

Summary of Historical Catch Information

The landings data track the perception of stock status showing a decline over the time series even with all the outside influences of market and availability. However, this information cannot be used for defining a reliable LRP because of the high inter-annual variability.

ACOUSTIC SURVEY INDEX

Automated acoustic recording systems deployed on commercial fishing vessels have been used since 1997 to document the distribution and relative abundance of Atlantic herring in the Bay of Fundy and coastal Nova Scotia (Power and Melvin 2010). A standardized survey design for spawning grounds was adopted in 1999 (Melvin and Power 1999, Power et *al.* 2003) and a calibration integration factor (CIF) has been incorporated into the estimates from 2001 onwards. The acoustic surveys are used as an index of relative abundance, not as absolute estimates of biomass, as was agreed to at the 2011 Framework Assessment (DFO 2011b). As such, the acoustic survey index is used to monitor trends in biomass on the spawning grounds, not to estimate total biomass. The acoustic survey data for German Bank and Scots Bay are shown in Figure 7 scaled to the 2005 to 2010 average.

Although the time series is short, in the absence of an analytical model and with the evidence of the large decline of fish on two out of four spawning grounds, decrease in overall catch and targeting of juveniles in the fishery, as well as the science advice indicating the need for rebuilding, it is proposed that the 2005 to 2010 average survey value be identified as the LRP for SWNS/BoF herring (German Bank and Scots Bay).

Summary of Acoustic Survey Index

Although the time series is short, it is proposed that the 2005 to 2010 average survey value be identified as the LRP for SWNS/BoF herring (German Bank and Scots Bay).

UNCERTAINTY

Uncertainty should be incorporated in the calculation of stock status and biological reference points (DFO 2009a). The proposed LRP for the SWNS/BoF herring spawning component is based on the acoustic survey index and the estimates for that index and the 95% standard errors are shown in Figure 7.

The appropriate risk to consider when adhering to the Fishery Decision-Making Framework incorporating the PA is the probability and severity of the impact from management actions on stock productivity. In the Framework, the management of this risk is expressed by the identification and position of reference points, the changing severity of management actions that are chosen as stock status changes and the tolerance for stock declines (DFO 2009a).

LIMIT REFERENCE POINT AND CONCLUSION

With the evidence of the decline in spawning grounds (Figures 1 and 2), targeting of juveniles in the fishery (Figures 3 and 4), declines in catches (Figures 5 and 6), as well as the science advice indicating the need for rebuilding (Table 1), it is proposed that the 2005 to 2010 average acoustic survey value (Figure 7) be identified as the conservation LRP for SWNS/BoF herring (German Bank and Scots Bay). The stability at the 2005-2010 level is support for this as the LRP and provides data from which to select a point, below which, the risk of serious harm is unacceptable. Other considerations that lead to the selection of this point relate to the objective of avoiding negative impacts to the ecosystem and long-term loss of fishing opportunities. Ecosystem considerations include herring's role as a forage fish, and long-term loss of fishing opportunities in the case of stock collapse and possible decades required for recovery to occur.

It is proposed that a three year running average be used to determine the state of the SWNS/BoF herring (German Bank and Scots Bay) in relation to the LRP because of the variability in the annual acoustic point estimates. Given the life history characteristics of herring, the three year running average is more appropriate for detecting the trend and would smooth out the inter-annual variability.

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Table 1. Advice from advisory and research documents, 1994 to 2011.

Fishery Year	Advice	Advisory Document	Research Document
1990	...the available information indicates that the stock size increase of the early 1980's has ended and the **stock may now be decreasing** because there have been no strong year classes since 1983. Catches in 1991 should not exceed the recent maximum of about 125,000t.	CAFSAC 90/4	91/58
1991	... uncertainties about catches preclude CAFSAC from completing an analytical assessment of divisions 4WX herring. Considering that **no strong year classes have been detected recently**, CAFSAC suggests that the long-term average catch, of about 125,000t, be used as a guide to possible catches in 1992.	CAFSAC 91/14	92/69
1992	CAFSAC is **not able to assess** the implications of setting the TAC in the order of advised catches because it is impossible to predict to what extend under-reporting will prevail.	CAFSAC 92/10	93/76
1993	While there is **insufficient information to recommend a change in previous advice**, there was concern that continued uncertainties regarding the landings and in the indices preclude an analytical assessment. It is recommended that work towards an analytical assessment continue.	DFO SSR-1993	94/88
1994	An analytical assessment conducted with the revised catch at age data and calibrated with larval survey data indicated an increase in biomass during the 1980's, peaking in 1987, followed by a moderate decline. ...a VPA matching the most recent larval survey point **indicates that the population has decreased** to approximately 200,000t.		95/83
1995	There have been no strong year-classes since 1983 and there **continues to be concern for the state of this stock.** The spawning stock biomass has decreased considerably in recent years, and while it is estimated to have increased slightly in the last year, it is still estimated to be between 100,000 and 200,000t.		96/28
1996	The SW Nova Scotia spawning component **has declined in recent years**. Landings in 1996 were the lowest in three decades, reflecting the lowest quota on record for this fishery. The fishery exhibited a poor age composition, dominated by a single (1992) year-class.	B3-03 (1997)	97/61
1997	Since the current age composition remains narrow, and a new approach (acoustics) has been used for determination of biomass, **fishing below F0.1 would again be prudent**.	B3-03 (1998)	98/72
1998	Assuming that the 520,000t observed SSB is a minimum, fishing at 105,000t in 1999 **should generate an F less than F0.1** which **will allow continued growth of SSB** and further improvement of age composition.	B3-05 (1999)	99/64
1999	The *stock size appears to have increased since 1994*, and there has been a substantial contribution to SSB by the large 1996 year-class, but there is insufficient spawning in several traditional areas, and a lack of old fish in the population. Catches similar to those of the past two years (less than 100,000t) and use of the "survey, assess, then fish" protocol on spawning grounds should generate F less than F0.1.	B3-03 (2000)	2000/065

Fishery Year	Advice	Advisory Document	Research Document
2000	This evaluation suggests that there has been a deterioration rather than improvement in stock status in 2000 and that the conservation objectives specified for this fishery are not being met. Catches in the year 2001 should be reduced to below that of the past three years. However, **there has been little, if any, evidence of rebuilding of this population** in the recent past when catches have been 77,000t – 85,000t.	B3-03 (2001)	2001/057
2001	**Conservation objectives** of maintaining a balanced age composition and maintenance of spawning on all spawning grounds **have not been met**.	B3-03 (2002)	2002/045
2002	Recent *good recruitment is expected to result in continued positive development of SSB*, age composition and re-occupation of spawning grounds with catch levels of recent years. Increasing catches may still result in improvement but at a lower rate; however, a large increase in catches could compromise improvement.	2003/027	2003/035
2003	Although acoustic surveys continue to show an SSB of approximately 505,000t, there has been a **deterioration in the state of the stock**. There has been insufficient progress towards conservation objectives in recent years.	2004/34	2004/040
2004	This assessment has **confirmed a further deterioration** in the state of the resource noted in the previous assessment. However, the change in use of acoustics as a relative rather than absolute abundance index has resulted in large change in the perception of the resource.	2005/033	2005/023
2005	None of the conservation objectives specified for this fishery are being met. This assessment has confirmed a **continued deterioration** in the state of the resource, as noted in previous assessments. A harvest strategy that allows rapid population rebuilding is strongly recommended.	2006/031	2006/049
2006	Most of the conservation objectives specified for this fishery are not being met. This assessment **indicates the low level of the resource** noted in previous assessments.	2007/023	2007/040
2007	This assessment *indicates an improvement from the low level of the resource* noted in recent assessments. A harvest strategy that exercises **continued caution to facilitate further rebuilding is strongly recommended**.	2008/023	2008/023
2008	This assessment indicates **little improvement from the low level of the resource** noted in recent assessments.	2009/035	2010/111
2009	This assessment *indicates improvements from the low level of the resource* noted in the previous assessment, e.g., SSB estimated from the acoustic surveys is approaching the series average (1999-2008). A harvest strategy that exercises continued caution to facilitate further rebuilding is recommended.	2010/021	2010/112
2010	This assessment indicates **stability at the lower level from 2005-2010 and shows little or no signs of improvement**. This lack of rebuilding despite reduced catch levels in recent years is cause for concern.	2011/046	in progress

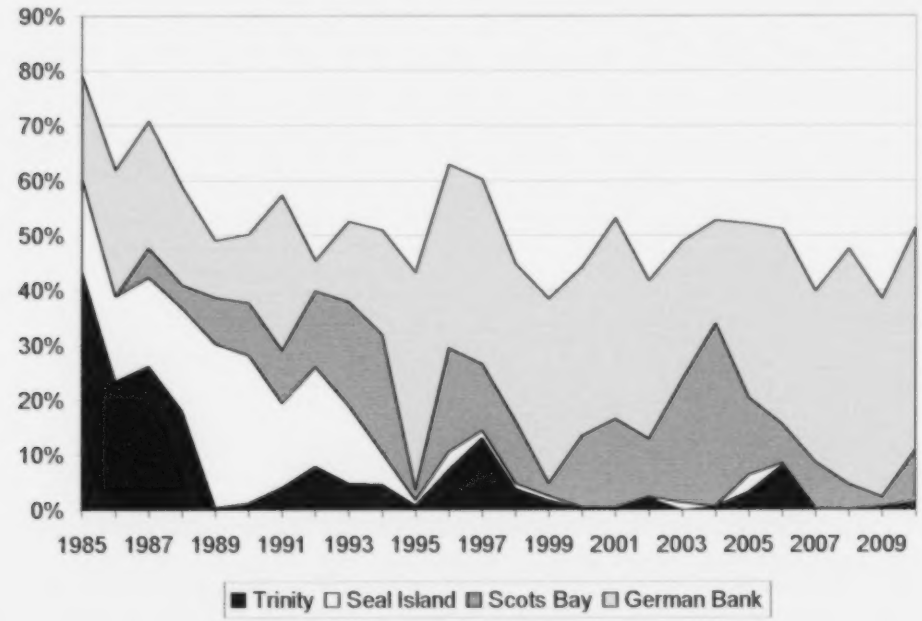

Figure 1. Spawning ground area catches as a proportion of the overall purse seine logbook catch.

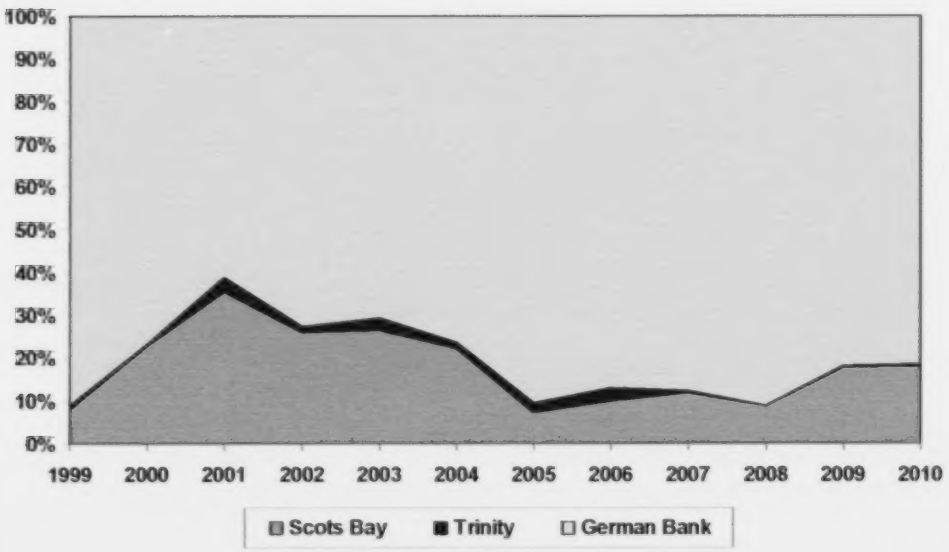

Figure 2. Proportion of the total acoustic survey estimates by spawning ground and year, 1999 to 2010.

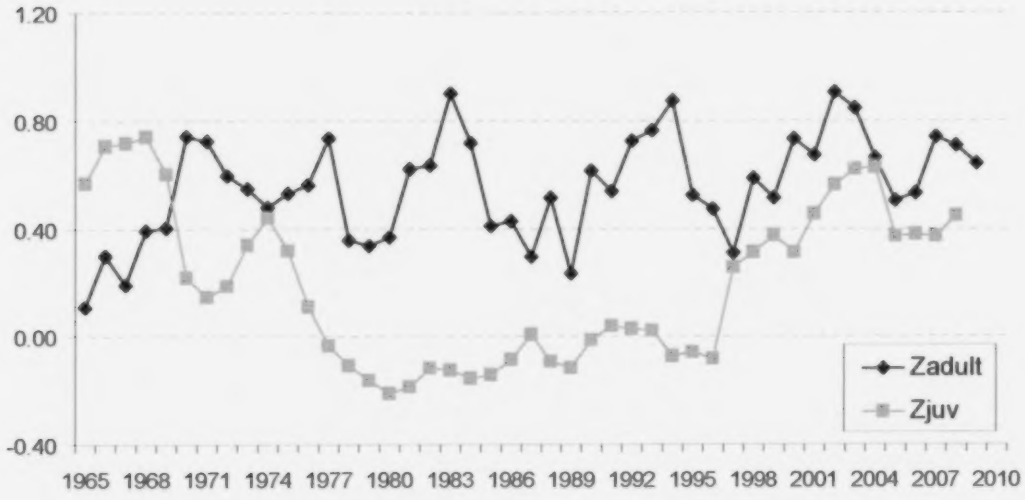

Figure 3. Three-year weighted averages of total mortality (Z) for adults and juveniles.

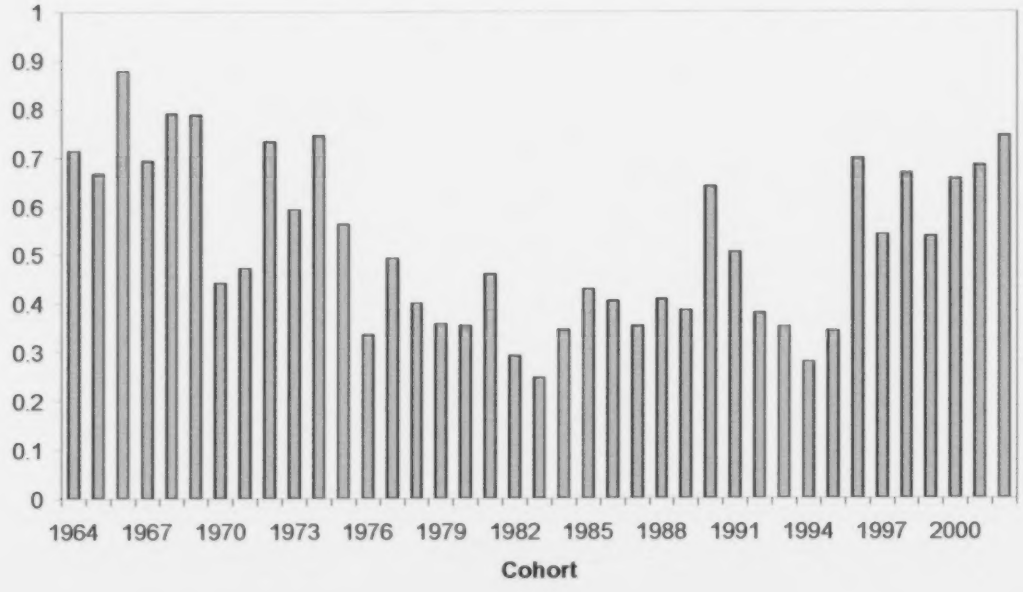

Figure 4. Proportion of the total catch from a cohort that is caught at ages 1 to 3.

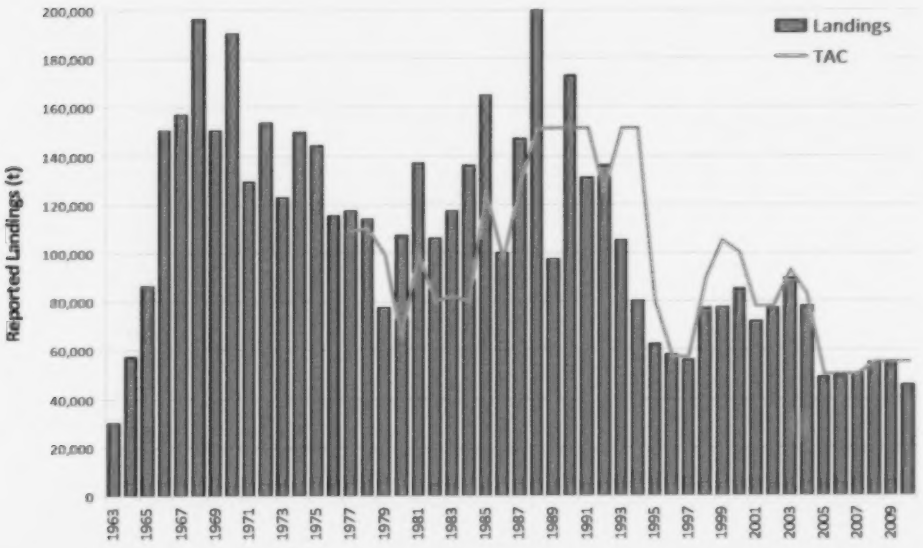

Figure 5. Summary of the total 4WX reported herring landings (tonnes) from 1963 to 2010 and quota from 1977 to 2010.

Figure 6. The 5-year moving average of reported landings for the SWNS/BoF herring fishery from 1963-2010.

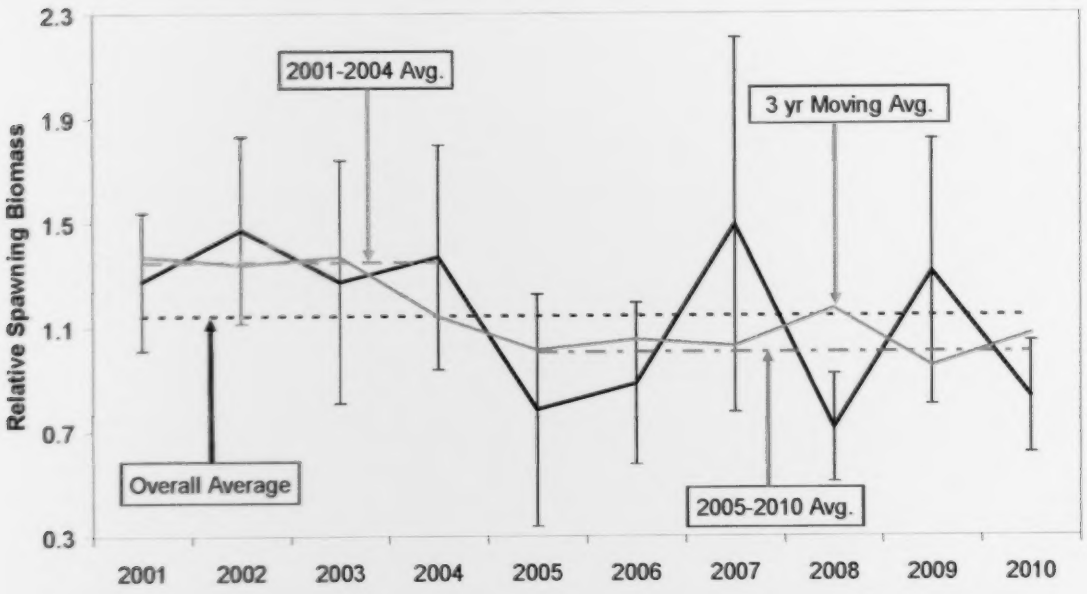

Figure 7. Relative spawning stock biomass index (with 95% standard errors) and the calculated 3-year moving average for the SW Nova Scotia/Bay of Fundy spawning component (German Bank and Scots Bay), scaled to the period 2005 to 2010.